The measurement of the calibers of the branches of the aortic arch: a statistical investigation of 430 living subjects using ultrasonic

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University of Florence, Italy
* Institute of Gerontology and Geriatric Medicine
** Department of Human Anatomy and Histology

The Measurement of the Calibers of the Branches of the Aortic Arch: A Statistical Investigation of 430 Living Subjects using Ultrasonic Tomography

Claudio Macchi* - Fabrizio Giannelli* - Claudio Catini**

Key words: caliber, aortic arch branches, ultrasonic tomography.

SUMMARY

Using Doppler ultrasound, we have measured the calibers of the branch arteries of the aortic arch in 430 subjects (230 men and 200 women; age range: 18 to 84 years). These included: the brachiocephalic trunk, the subclavian arteries, the common carotid arteries, the internal and external carotid arteries, and the vertebral arteries.

Statistical analysis of the values obtained yielded a number of interesting results. The average caliber of the arteries of the women examined was lower than that of the men. Nonetheless, the statistical difference in the arterial diameters of the two sexes was not significant, with the exception of the left subclavian artery. In the case of this artery, its caliber was larger among the men than the women. However, this relationship was not confirmed in the right subclavian artery.

The left vertebral artery was larger than the right one. This difference was statistically significant among the women ($p<0.05$), but not among the men ($p=ns$).

The right subclavian artery was larger than the left one by a statistically significant margin ($p<0.05$), but the statistical significance may be accounted for by the values in the women alone ($p<0.02$). When the men were considered separately, the difference between right and left did not achieve statistical significance ($p=ns$).

There was no statistically significant correlation between arterial caliber and either height or body weight.

Furthermore, the caliber of the arteries examined increased with age, but not in a statistically significant manner.

The mean values of the single arteries examined were lower than those described by the principal investigators of the cadaveric studies to which we have referred. However, with three

exceptions, the differences were not statistically significant. In the case of the subclavian and internal and external carotid arteries, our values were lower by a statistically significant margin.

INTRODUCTION

Insofar as they are extremely discordant, the data in the literature regarding the caliber of the vessels of the aortic arch are very interesting. For example, the mean diameter of the brachiocephalic trunk has been reported by Adachi (1928) as 11 mm, by Testut and Latarjet (1959) as 12 mm, by Falcone (1950) and Davies and Davies (1962) as 14 mm, and by Chigi as 15 mm. All the investigators observed a larger caliber in men as compared with women.

With respect to the subclavian artery, Adachi (1928) has reported the mean diameter as 8 mm, Juster (1953) between 6.7 and 9.5 mm, and Testut and Latarjet between 11 and 12 mm. All three reports agree that the subclavian artery is larger in men than in women, but they disagree on the relationship between right and left. The right subclavian artery has been considered larger than the left by Hyrtl (1893) and Pensa and Favaro (1953), but it has been observed to be smaller by Loreti (1966).

As regards to common carotid artery, Adachi (1928), Kani (1910), and Schiele-Wiegandt (1880) have reported the mean diameter as 7 mm, while Muratori and Rossatti (1951) have reported it as a little less than 7 mm. They also agree that the arterial caliber is larger in men than in women. Romiti (1890) has found that the arterial caliber was larger on the right. This has been confirmed by Lambertini (1978) and Loreti (1966), who have found the left to be larger.

The mean caliber of the vertebral arteries has been reported as 6.1 mm by Vierordt and Versari (1932), as 4.5 mm by Romiti (1890), and as 4-5 mm by Luschka (1867). Cavatorti (1908) has reported that the mean caliber varied as much as 1 to 8 mm.

Variable mean calibers have been reported for the internal carotid artery. On the one hand, Luschka (1867) has found that it varied from 4 to 6.2 mm; on the other, Peli (1902) has reported values from 9 to 9.8 mm. Other investigators have found intermediate values.

Finally, the mean caliber of the external carotid artery has been found to range from 3.8 to 5.8 mm by Luschka to 7 mm by Peli (1902).

The aim of this study is to determine as precisely as possible the caliber of the vessels under examination. Using ultrasonography in living patients, it is possible to exactly measure the internal diameters of the arteries with an accurancy of tenths of millimeters (see *fig. 1*). The precise measurement of blood vessels is difficult in the cadaver, since the blood vessels undergo evident structural and morphological changes. In part, this is due to the absorption of fluids by the vessel wall, with a consequent changes in the internal diameter. In the cadaver, the determination of

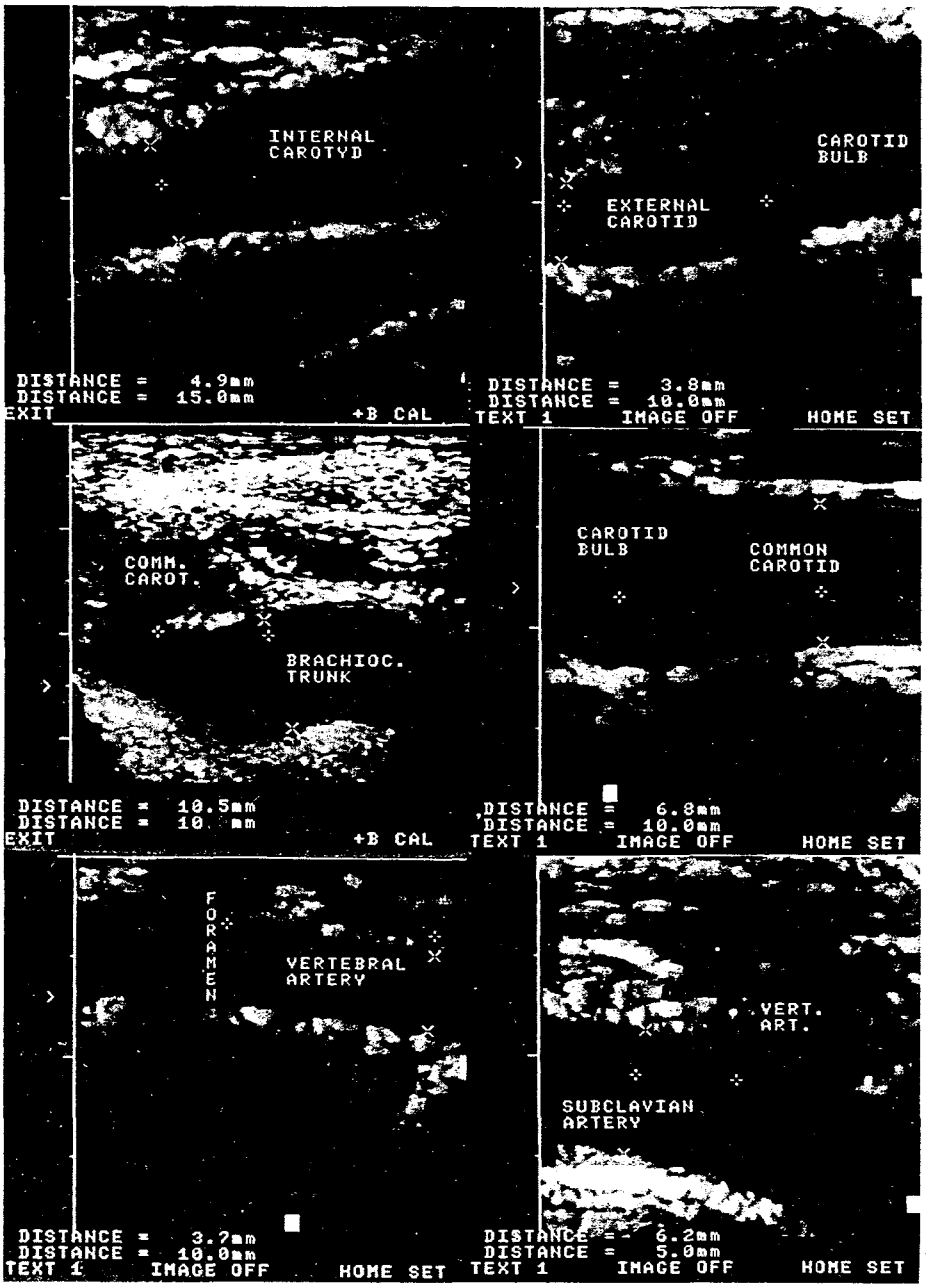


Fig. 1 - Method of visualization and measurement of the caliber of the arteries examined using Doppler ultrasonography.
Calipers: × ×: measurement of caliber,
+ +: measurement of the distance from the reference points.

the internal diameter of the artery is complicated by the fact that the measurement is derived from a measurement of the circumference, rather than directly. This requires a section of the artery to be longitudinally opened and distended. When this method is employed, the internal caliber is very similar to the external.

Using our ultrasonographic data, we have performed statistical correlations among the mean values of the internal calibers of the arteries under consideration with regard to side (left or right), sex, body weight, height, and age. Precise knowledge of the caliber of the afferent cerebral vessels is important for the evaluation of cerebral blood flow under normal and pathological conditions.

MATERIALS AND METHODS

We have examined 430 healthy subjects (230 men and 200 women; age range: 18 to 84 years). The subjects were selected from patients who had been referred to us and found to have no vascular pathology.

Using Doppler ultrasonography, the internal calibers of the following arteries were measured in each subject, as demonstrated in *Figure 1*: the brachiocephalic trunk (1 cm before its bifurcation), the subclavian arteries (½ cm after the origin of the vertebral arteries), the vertebral arteries (1 cm before their entrance in the transverse foramina of the C6 vertebra), the common carotid arteries (1 cm before the carotid bulb), and the internal and external carotid arteries (1 cm after their origin).

A 7.5-MHz Acuson 128 Doppler ultrasound system was used to measure the arterial calibers.

RESULTS

The mean values of the internal arterial diameters of the subjects we examined are presented in *Table 1*.

The mean caliber of the brachiocephalic trunk was greater in men than in women. This difference was statistically significant ($p < 0.01$).

The statistical data regarding the subclavian arteries were particularly interesting. Our data do not concur with previous studies that have shown no difference between right and left. On the contrary, our data indicate that the mean caliber of the right subclavian artery is larger than that of the left. This difference were statistically significant ($p < 0.05$). When men and women were considered separately, this statistically significant predominance of right over left was confirmed among the female subjects ($p < 0.02$). However, the statistical difference was not confirmed among the men ($p = ns$).

When the mean caliber of the subclavian arteries of the men was compared with that of the women, the left subclavian artery of the men was found to be larger than that of the women ($p < 0.05$). However, there was no significant difference

TABLE 1

	Right		Left	
	Male	Female	Male	Female
Brachioc. trunk	11.59±1.23	9.88±1.51		
Subclavian artery	6.59±0.66	6.26±0.63	6.31±0.87	6.03±0.75
Vertebral artery	3.22±0.87	2.90±0.53	3.32±0.59	3.30±0.59
Common carotid A.	7.13±0.42	6.60±0.75	7.37±0.47	6.56±0.80
Internal carotid A.	4.96±0.58	4.76±0.73	4.85±0.59	4.80±0.70
External carotid A.	4.10±0.65	3.60±0.49	4.02±0.51	3.60±0.53

between the men and women when the right subclavian artery was considered ($p = ns$). With respect to the correlation among the values of the calibers of the right and left subclavian arteries in each sex, the value could be explained as a simple sampling fluctuation only in the men. Thus, the coefficient of correlation differed significantly from 0.

With respect to the mean calibers of the vertebral arteries, the left was found to be larger than the right, but the difference was not statistically significant (see *fig. 4*). When they were analyzed according to sex, the difference between left and right in the women (see *fig. 5*) was found to be statistically significant ($p < 0.05$), but this was not so among the men ($p = ns$). When the mean values of the calibers of the respective arteries of the men and women were compared, there were no statistically significant differences ($p = ns$).

The only relevant data concerning the common carotid artery was that the left was larger than the right in men (see *fig. 6*). However, in this case also, the difference was not statistically significant.

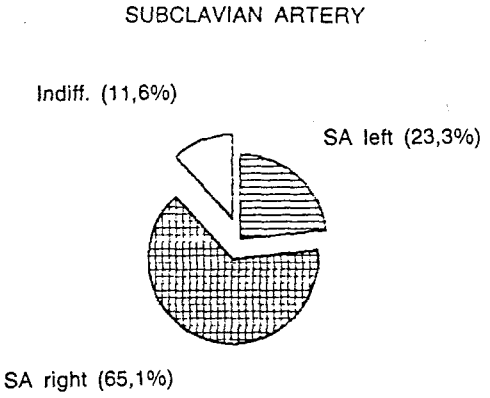
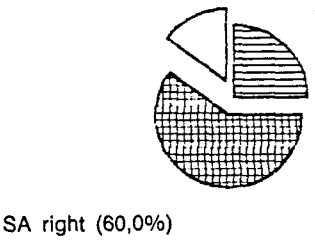


Fig. 2

SUBCLAVIAN ARTERY
FEMALE SEX



SUBCLAVIAN ARTERY
MALE SEX

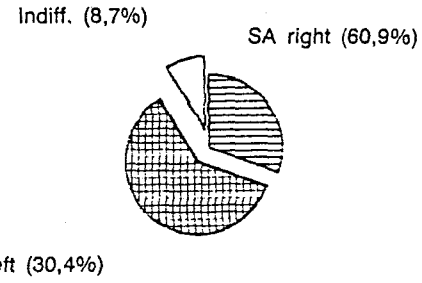


Fig. 3

VERTEBRAL ARTERY

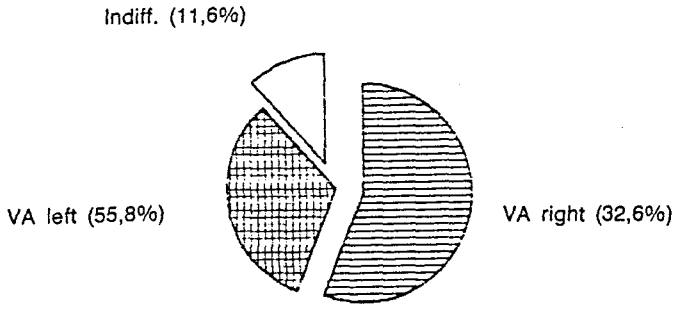
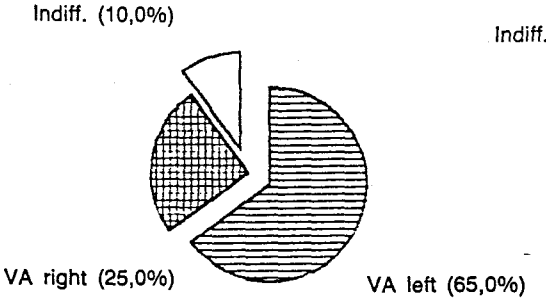


Fig. 4

VERTEBRAL ARTERY
FEMALE SEX



VERTEBRAL ARTERY
MALE SEX

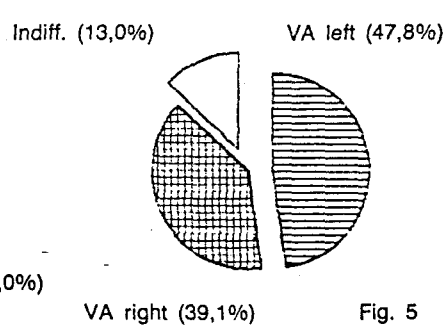


Fig. 5

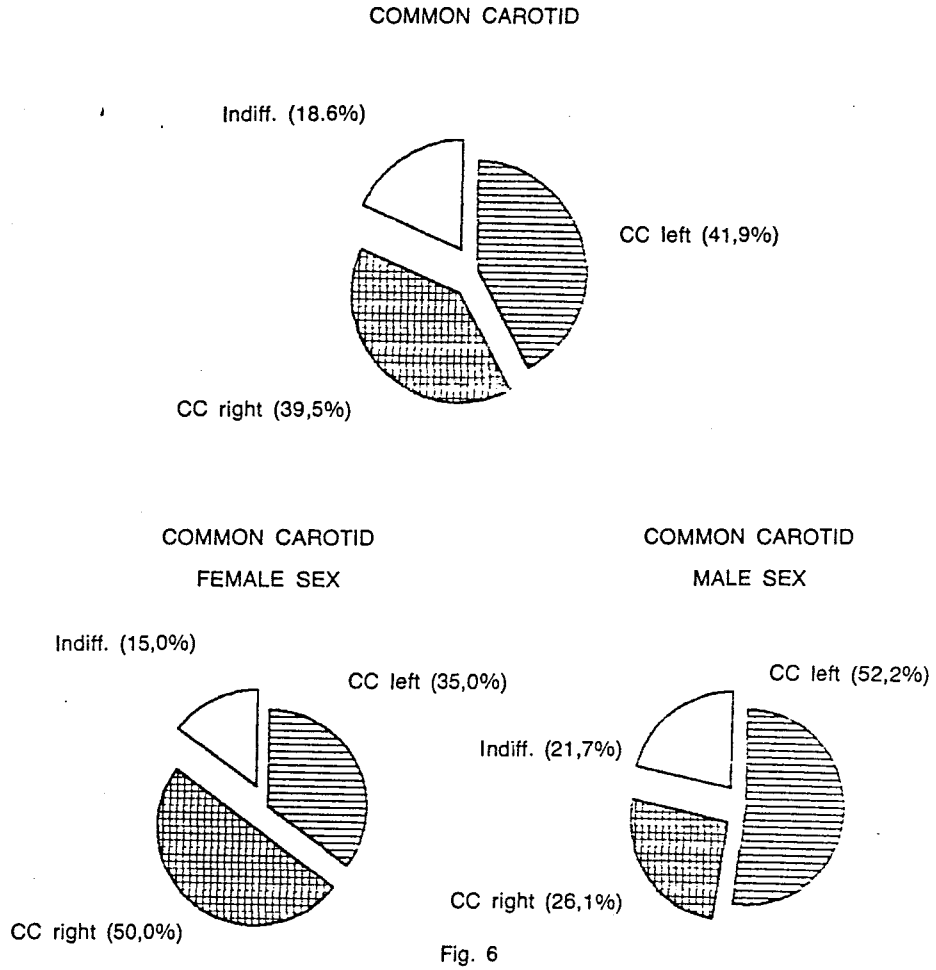


Fig. 6

Among the women, the right internal carotid artery was found to be larger than the left (see *fig. 7*), but this difference was not statistically significant.

Similarly, the right external carotid artery was found to be larger than the left among women (see *fig. 8*), but again this difference was not statistically significant.

Among the values for the calibers of the common, internal, and external carotid arteries, there were no statistically significant correlations in the variations of the values of mean caliber, either between the 2 sides (among subjects of the same or opposite sex) or between the 2 sexes ($p = ns$).

Among all the groups of arteries considered, we have found no statistically significant correlations among vessel caliber, body weight, or height ($p = ns$). There was found to be an increase in caliber with age, but this relationship was not statistically significant.

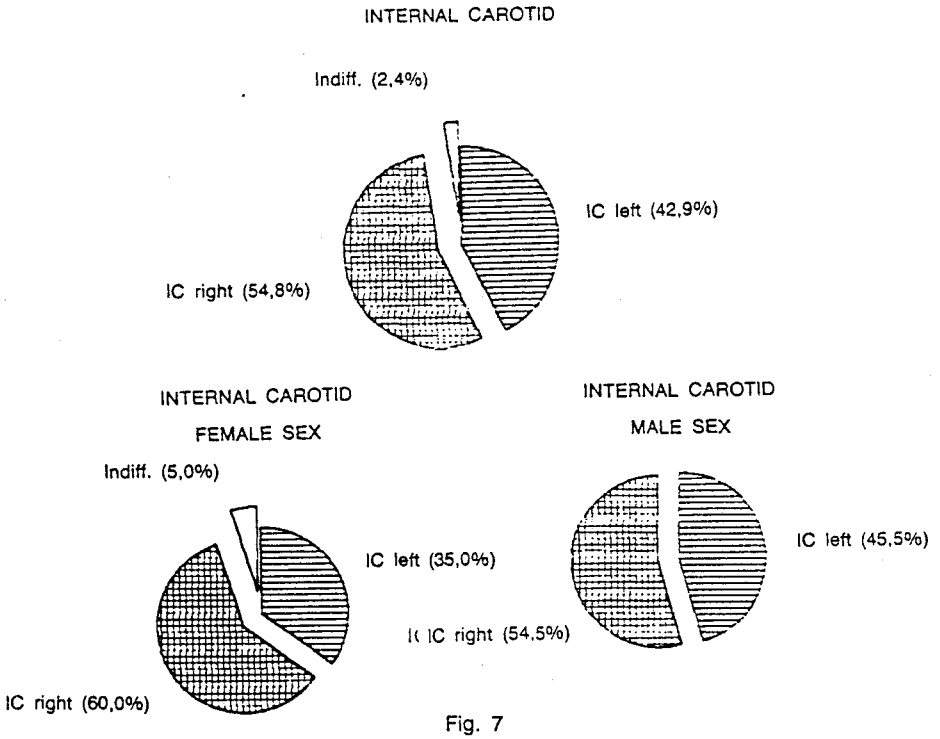

INTERNAL CAROTID
Indiff. (2,4%)
IC left (42,9%)
IC right (54,8%)
INTERNAL CAROTID
FEMALE SEX
Indiff. (5,0%)
IC left (35,0%)
IC right (60,0%)
INTERNAL CAROTID
MALE SEX
IC left (45,5%)
IC right (54,5%)

Fig. 7

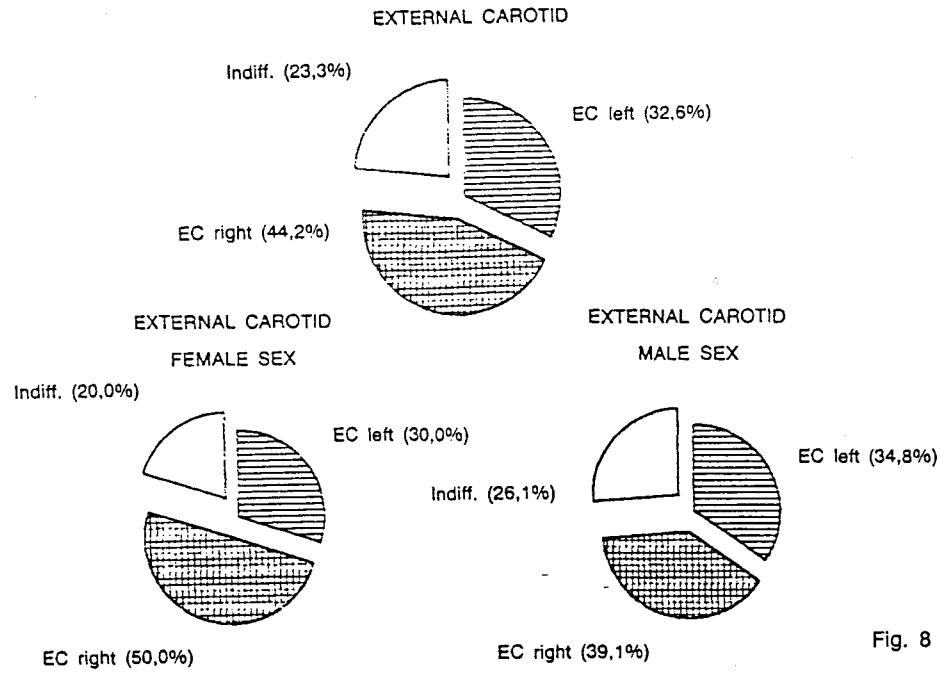

EXTERNAL CAROTID
Indiff. (23,3%)
EC left (32,6%)
EC right (44,2%)
EXTERNAL CAROTID
FEMALE SEX
Indiff. (20,0%)
EC left (30,0%)
EC right (50,0%)
EXTERNAL CAROTID
MALE SEX
Indiff. (26,1%)
EC left (34,8%)
EC right (39,1%)

Fig. 8

DISCUSSION AND CONCLUSIONS

Our data regarding the brachiocephalic trunk concord with those of Adachi (1928) and Testut and Latarjet (1959).

As far as the subclavian artery is concerned, the values of mean caliber that we have found are lower than those reported by the other investigators cited in the introduction. In fact, compared to the results of Testut and Latarjet (1959), our findings are lower by a statistically significant margin. Hyrtl (1893) and Pensa and Favaro (1935) have confirmed the finding that the right subclavian artery is larger than the left, while the results of Loreti (1966) are conflicting.

With respect to the common carotid artery, our study generally confirms the findings of the investigators cited in the introduction. The same may be said for the internal and external carotid arteries. The only exception with regard to these two arteries is the data reported by Peli (1902), whose results are greater than ours by a statistically significant margin ($p<0.05$).

Our values for the mean calibers of the vertebral arteries are generally lower than those that have been reported by the other investigators cited in the introduction. However, the differences are not statistically significant.

The correlations among our measured mean calibers and those derived from measured circumference that have been reported by Gulisano, Zecchi, Pacini, Orlandini (1982) are interesting. The data correlate fairly well, even though they were obtained by different methods. Our data reflect the mean internal caliber of vessels in living subjects rather than the arterial circumference in cadavers. The correlation was evident in the case of the vertebral arteries, but there was no such correlation in the case of the subclavian arteries. Moreover, our data are in agreement with these investigators with regard to the correlation among arterial dimensions, sex, and age.

Undoubtedly, it is difficult to correlate the results of studies that apply different methods. We believe that is correct to measure the caliber at the point at which the artery maintains an invariable caliber along the longest trajectory. Certainly, if we had averaged the values by taking into account the calibers of the arteries at their origin, the results would have been considerably different. For example, the caliber of the internal carotid artery near its origin is nearly double that at which we made our measurements. Nevertheless, the good correlation with the best cadaveric anatomic studies (Gulisano, Zecchi, Pacini, Orlandini, 1982) has confirmed the validity of our system of measurement.

It is evident that a 70% stenosis in one artery that has a mean caliber of 4 mm has a hemodynamic significance different from that of an artery that has a mean caliber of 7 mm. We believe that knowledge of the caliber of the supra-aortic vessels, especially with regard to asymmetry, is important, both for its diagnostic, angiographic implications and for the prognostic assessment.

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REFERENCES

Ackerman RH, Vigneault LA, Pryor DS, Taveras JM, 1979. Real-Time ultrasound scanning of the carotid artery as part of a battery of tests for non-invasive diagnosis of carotid disease. Acta neurol. scand. (Suppl. 72) 60: 464-465.

Adachi B, 1928. Das Arteriensystem der Japaner. Maruzen, Kioto.

Aaslid R, (ed.), 1986. Transcranial doppler sonography. Springer, Wien.

Bharadvai BK, Mabon RF, Giddens DP, 1982. Steady flow in a model of the human carotid bifurcation. Part I-Flow visualization. J. Biomech. 15: 349-362.

Cavatorti P, 1908. Il tipo normale e le variazioni delle arterie della base dell'encefalo. Monit. Zool. ital., Firenze 19: 248-258.

Chiarugi G, Bucciante L, 1975. Istituzioni di Anatomia dell'Uomo, Vallardi, Milano.

Dauzat M, Laroche JP, De Bray J, Juhel P, Becker F, Cesari JB, Jonnart L, Domergue A, Carette J, Duvauferrier R, Heyden D, Maugin D, Vonsgouthi S, Davinroy M, 1986. Pratique de l'ultrasonographie vasculaire (Doppler echographie), Vigot, Paris.

Davies DV, Davies F, 1962. Gray's Anatomy, Longmans, London 754-865.

Falcone C, 1950. Trattato di Anatomia umana, I. Vallardi Milano, 468-606.

Franceschi C, Luizy F, Jardin M, Martelli L, Tanitte M, 1980. La carotide externe sous-parotidienne: un point de compression méconnu mais de grande valeur diagnostique: Ultrasons I: 295-298.

Garth KE, Carroll BA, Summer EG, 1983. Duplex ultrasound scanning of the carotid arteries with velocity spectrum analysis. Radiology, 147: 823-827.

Ghigi C, 1946. Anatomia umana normale, I.L.U.C.E., Bari, 420-441.

Gray's Anatomy, Longman Group L.T.D., London 1989.

Gulisano M, Zecchi S, Pacini P, Orlandini GE, 1982. The behaviour of some human arteries as regards the corrected circumference: a statistical research. Anat. Anz., Jena 152: 341-357.

Hennerici M, Neuerburg HD, 1991. Diagnostica vascolare con ultrasuoni. Il Pensiero Scientifico Editore, Roma.

Hennerici M, Hulsbomer HB, Hefter H, Lammerts D, Rautemberg W, 1987. Natural history of asymptomatic extracranial arterial disease. Results of a long-term prospective study. Brain 110: 777-791.

Hyrtl G, 1893. Istituzioni di anatomia dell'uomo. Pasquale, Napoli, 781-826.

Kani I, 1910. Systematische Lichtungs und Dickenmessungen der groben Arterien und ihre Bedeutung fur die Patologie der Gefabe. Virchows Arch. Path. Anat., Berlin 201: 45-78.

Lambertini G, 1978. Anatomia Umana, I. Piccin, Padova, 416-486.

Lang G, Bushe KA, Buschmann W, Linnert D, 1979. Kopf, teil B., Gehirnund Augenschadel. In von Lanz, T., Wachsmuth: Praktische Anatomie. Ein lehr-und Hilfe-buch der Anatomischen Grundlagen arztlichen Handelns. Springer, Berlin.

von Lanz T, Wachsmuth W, 1955. Praktische Anatomie. Ein lehr und Hilfsbuch der Anatomischen Grundlagen arztlichen Bd.1/2 Hals Springer Berlin.

Loreti F, 1963. Elementi di Anatomia Generale e di Embriologia del cuore, del pericardio e dei vasi sanguiferi. Idelson, Napoli, 87-99.

Juster M, 1953. Calibre et valeur fonctionelle du tronc brachiocéhalique, de la carotide primitive et de la sousclavière. C.R. Ass. Anat., Nancy, 40: 652-657.

Luschka H, 1902. Cit. by Peli G.

Muratori G, Rossatti B, 1951. Modificazioni dimensionali e strutturali delle arterie anonime, succlavia e carotide comune con l'età. Boll. Soc. ital. Biol. sper., Napoli, 27: 617-627.

Orlandini GE, 1970b. Sulle asimmetrie di ampiezza delle arterie carotidi interne e delle arterie vertebrali nell'uomo. Studi sassaresi, 48: 1-7.

Peli G, 1902. Il calibro delle principali arterie della base dell'encefalo nei sani di mente e negli alienati. Boll. Sci. Med., Bologna, 73: 537-347.

Pensa A, Favaro G, 1935. Trattato di Anatomia Umana Sistematica, II. Utet, Torino, 44 to 51.

Pernkopf E, 1963. Atlante di Anatomia Sistematica e Topografica dell'uomo, Piccin Editore, Padova.

Romiti G, 1890. Trattato di Anatomia dell'Uomo, I. Vallardi, Milano, 803-928.

Schiele-Wiegandt V, 1880. Ueber Wanddi und Umfang der Arterien des menschlichen Korpers. Virchows Arch. path. Anat., Berlin, 82: 27-39.

Sobotta J, Becher H, 1974. Atlante di Anatomia dell'Uomo, Uses, Firenze.

Spalteholz W, SPanner R, 1977. Atlante di Anatomia Umana, Vallardi ed. Milano.

Testut L, Latarjet A, 1959. Trattato di anatomia umana, II, UTET, Torino, 571-879.

Testut L, Jacob O, 1974. Trattato di Anatomia Topografica, UTET, Torino.

Versari R, 1932. Trattato di Anatomia umana, II, Vallardi, Milano, 393-398.

Vierordt H, 1906. Anatomische, physiologische und physikalische Daten und Tabellen. Fischer, Jena, 172-177.

Address:
Prof. Claudio Catini
Dipartimento di Anatomia
Umana Normale ed Istologia
Policlinico di Careggi
50134 Firenze